

DESCRIPTION

Electret Condenser**Technical Field**

[0001] The present invention relates to an electret condenser including a vibrating
5 electrode and a fixed electrode, and more particularly relates to an electret condenser
formed using a MEMS (Micro Electro mechanical Systems) technology.

Background Art

[0002] Conventionally, in electret condensers, which are usually applied to elements for
condenser microphones and the like, a structure is employed which includes an electret
10 film as dielectrics having a permanent electric polarization and an air gap (cavity) layer
between a fixed electrode and a movable electrode which compose a parallel-plate
condenser.

[0003] In such electret condensers, the thickness of the air gap layer has a direct
relationship with a capacitance value of the condenser and involves significant influence
15 on performance of the microphone and the like. Specifically, as the air gap layer is thin,
the sensitivity of the microphone or the like increases. In contrast, when variation in
thickness of the air gap layer in the manufacturing process is large, variation in sensitivity
increases in the microphone and the like. Accordingly, the air gap layer provided in the
electret condenser is desired to be thin and has less variation in thickness in the
20 manufacturing process.

[0004] In recent years, in order to reduce the thickness of the air gap layer and variation in
the thickness thereof in the manufacturing process, a structure of an air gap layer and a
method for manufacturing it which utilize a microfabrication technology have been
proposed. Specifically, for example, a technique has been proposed in which part of a Si
25 (silicon) substrate is removed by wet etching using potassium hydroxide to form a recess
(see Patent Document 1).

Patent Document 1: Japanese Patent Application Laid Open Publication No.

2002-345088A

Disclosure of Invention

Problems that the invention is to solve

[0005] However, in order to realize small-size and high-performance appliances in a recent tendency, smaller-size and higher-performance electret condensers are desired of which characteristic variation is small.

[0006] Under the circumstances, formation of an electret condenser including a fixed electrode and a movable electrode is being tried with the use of the MEMS technology. However, this presents a problem that in forming an air gap between the fixed electrode and the movable electrode by wet etching, the fixed electrode and the movable electrode stick to each other by surface tension of an etching solvent or a cleaning solvent, that is, a problem that an air gap layer of a desired thickness cannot be formed.

[0007] The present invention has been made in view of the foregoing and has its object of preventing electrodes from sticking to each other in forming an air gap in an electret condenser to control the thickness of an air gap layer with high precision.

Means for solving the problems

[0008] To attain the above object, an electret condenser of the present invention includes: a first film including a first electrode; a second film including a second electrode and an electret film; a first insulting film formed between the first film and the second film; and an air gap formed by removing part of the first insulating film, wherein respective parts of the first film and the second film exposed in the air gap are formed of a second insulating film.

[0009] The present invention renders it possible to implement a highly-reliable, small-size, and high-performance microphone. It becomes further possible to widely supply various practical devices equipped with the microphone to the public.

Brief Description of the Drawings

[0010] [FIG. 1] FIG. 1(a) and FIG. 1(b) are constitutional diagrams of an electret condenser microphone (hereinafter referred to as ECM) according to one embodiment of

the present invention, wherein FIG. 1(a) is a plan view of the ECM, and FIG. 1(b) is a section of the ECM.

[FIG. 2] FIG. 2 is a circuit block diagram of the ECM according to the embodiment of the present invention.

5 [FIG. 3] FIG. 3 is a section of an electret condenser composing the ECM according to the embodiment of the present invention.

[FIG. 4] FIG. 4 is a plan view showing a lower electrode and a lead wire of the electret condenser composing the ECM according to the embodiment of the present invention.

10 [FIG. 5] FIG. 5 is a plan view of a silicon nitride film in a fixed film of the electret condenser composing the ECM according to the embodiment of the present invention.

[0011] 18 electret condenser

19 SMD

20 FET portion

15 21 printed circuit board

22 case for ECM

23 internal circuit of ECM

24 output terminal

25 output terminal

20 26 external terminal

27 external terminal

28 terminal

29 terminal

30 terminal

25 101 semiconductor substrate

102 silicon oxide film

103 silicon nitride film

	104	lower electrode
	105	silicon oxide film
	106	silicon nitride film
	107	leak hole
5	108	silicon oxide film
	109	air gap
	110	fixed film
	111	acoustic hole
	112	vibrating film
10	113	membrane region
	114	silicon nitride film
	115	lead wire
	116	opening
	117	opening
15	118	conductive film
	119	silicon nitride film

Best Mode for Carrying out the Invention

[0012] An electret condenser according to one embodiment of the present invention will be described by referring to a case applying it to an ECM as an example with reference to the accompanying drawings.

[0013] First, the ECM as an element employing the electret condenser of the present embodiment will be described.

[0014] FIG. 1(a) and FIG. 1(b) are constitutional diagrams of the ECM according to the present embodiment, wherein FIG. 1(a) is a plan view of the ECM, and FIG. 1(b) is a section of the ECM.

[0015] As shown in FIG. 1(a) and FIG. 1(b), the ECM of the present embodiment is so composed that an electret condenser 18, an SMD (surface mounting device) 19, such as a

condenser, and an FET (field effect transistor) portion 20 are mounted on a printed circuit board 21. Though not shown in FIG. 1(a), the printed circuit board 21 on which the electret condenser 18, the SMD 19, and the FET portion 20 are mounted is protected with a case 22.

5 [0016] FIG. 2 is a circuit block diagram of the ECM of the present embodiment.

[0017] As shown in FIG. 2, an internal circuit 23 of the ECM of the present embodiment includes the electret condenser 18, which is the electret condenser of the present embodiment as will be described later, the SMD 19, and the FET portion 20. Signals are output from an output terminal 24 and an output terminal 25 of the internal circuit 23 to an external terminal 26 and an external terminal 27, respectively. In an actual operation, when a signal at a voltage of, for example, approximately 2 V is input from a terminal 28 connected to the external terminal 26 via a resistor, a signal having an AC voltage of, for example, several tens of microvolts is output to a terminal 29 connected to the external terminal 26 via a condenser. The external terminal 27 and a terminal 30 connected thereto are connected to the output terminal 25 serving as a GND terminal in the internal circuit 23 of the ECM.

[0018] The electret condenser of the present embodiment will be described below. FIG. 3 is a section of the electret condenser of the present embodiment.

[0019] As shown in FIG. 3, the electret condenser of the present embodiment is a parallel plate condenser which includes, on a semiconductor substrate 101 having a region (hereinafter referred to as a membrane region 113) removed to leave the peripheral part thereof, a vibrating film 112 formed so as to cover the membrane region 113 and a fixed film 110 arranged above the vibrating film 112 as electrodes with an air gap 109 interposed therebetween. The vibrating film 112 includes a lower electrode 104 while the fixed film 110 includes a conductive film (upper electrode) 118.

[0020] Specifically, a silicon oxide film 102 is formed on the semiconductor substrate 101 on which the electret condenser of the present embodiment is mounted, and the membrane

region 113 is formed in such a manner that the semiconductor substrate 101 and the silicon oxide film 102 are removed partially so that the respective peripheral parts thereof are left.

In other words, the membrane region 113 is a region formed by partially removing the semiconductor substrate 101 so as to leave the peripheral part thereof for allowing the vibrating film 112 to vibrate upon receipt of pressure from outside.

[0021] A silicon nitride film 103 is formed on the silicon oxide film 102 so as to cover the membrane region 113. On the silicon nitride film 103, a lower electrode 104 and a lead wire 115 are formed which are made of the same conductive film. The lower electrode 104 is formed on the silicon nitride film 103 covering the membrane region 103 and a surrounding region thereof (part of an external region of the membrane region 113) while the lead wire 115 is formed so as to be in contact with the lower electrode 104 on part of the silicon nitride film 103 located outside the membrane region 113.

[0022] On each of the silicon nitride film 103, the lower electrode 104, and the lead wire 115, a silicon oxide film 105 and a silicon nitride film 106 are formed in this order. Thus, the vibrating film 112 is formed of the silicon nitride film 103, the lower electrode 104 made of the conductive film, the silicon oxide film 105, and the silicon nitride film 106 which are located within the membrane region 113. In the vibrating film 112, a plurality of leak holes 107 are formed to communicate with the air gap 109. The silicon nitride film 103 and the silicon nitride film 106 are formed so as to cover the entire surfaces of the lower electrode 104 and the silicon oxide film 105 including the inner wall faces of the leak holes 107. The silicon oxide film 105 is an electret film that accumulates charge.

[0023] Further, as shown in FIG. 3, the fixed film 110, which is formed of the conductive film 118 covered with the lower layer of a silicon nitride film 114 and the upper layer of a silicon nitride film 119, is provided above the vibrating film 112, that is, above the silicon nitride film 106. The air gap 109 is formed between the vibrating film 112 and the fixed film 110 in the membrane region 113 and the surrounding region thereof (part of an external region of the membrane region 113). In the other region, the silicon oxide film

108 is formed between the silicon nitride film 106 or the silicon oxide film 102 and the
~~fixed film 110. In other words, the air gap 109 is formed above a region including at least~~
the entirety of the membrane region 113 while the fixed film 110 is supported above the
vibrating film 112 by the silicon oxide film 108. The air gap 109 is formed by partially
5 removing the silicon oxide film 108 formed on the semiconductor substrate 101 and the
membrane region 113.

[0024] In sum, as a significant feature of the present embodiment, respective parts of the
fixed film 110 and the vibrating film 112 which are exposed in the air gap 109 are formed
of the silicon nitride films (the silicon nitride film 114 of the fixed film 110 and the silicon
10 nitride film 106 of the vibrating film 112, respectively), as shown in FIG. 3.

[0025] A plurality of acoustic holes 111 communicating with the air gap 109 are formed
in the fixed film 110 located above the air gap 109. Also, an opening 116 is formed in the
silicon oxide film 108 and the fixed film 110 including the silicon nitride film 114, so as to
partially expose the lead wire 115. The lower electrode 104 is electrically connected to a
15 gate of the FET portion 20 shown in FIG. 2 via the lead wire 115. Further, an opening
117 is formed in the silicon nitride film 119 composing the fixed film 110 so that the
conductive film 118 composing the fixed film 110 is exposed therethrough, whereby the
conductive film 118 is electrically connected to the GND terminal 25 in FIG. 2.

[0026] FIG. 4 is a plan view showing the lower electrode 104 and the lead wire 115 of the
20 electret condenser in the present embodiment. As described above, the lower electrode
104 and the lead wire 115 are formed of the same conductive film. Further, as shown in
FIG. 4, the lower electrode 104 is formed within the membrane region 103, and the
plurality of leak holes 107 are formed in the peripheral part of the lower electrode 104.
The lead wire 115 is formed for electrically connecting the lower electrode 104 to the
25 outside.

[0027] The reason why the lower electrode 104 is formed within the membrane region
113 will be described below. The capacitance of the condenser in the ECM depends on a

capacitance component that varies with the vibration of the vibrating film and a
~~capacitance component that does not vary with the vibration of the vibrating film.~~ When

a parasitic capacitance is increased, the capacitance component that does not vary with the
vibration of the vibrating film increases disadvantageously, so that the performance of the

5 ECM is largely influence thereby. In contrast, in the present embodiment, the lower
electrode 104 of the electret condenser is provided within the membrane region 113. This

eliminates a region where the lower electrode 104 overlaps the semiconductor substrate
101, eliminating a MOS (Metal Oxide Semiconductor) capacitance of a large area

composed of the lower electrode 104, the silicon oxide film 102, and the semiconductor
10 substrate 101. More specifically, the parasitic capacitance is limited only to a MOS

capacitor of a small area composed of the lead wire 115, the silicon oxide film 102, and the
semiconductor substrate 101. Consequently, the capacitance component (parasitic

capacitance) that does not vary in the condenser is prevented from increasing, attaining a
small-size and high-performance electret condenser.

15 [0028] Further, in the present embodiment, of the constitutional elements of the vibrating
film 112, namely, of the silicon nitride film 103, the lower electrode 104 formed of the

conductive film, the silicon oxide film 105, and the silicon nitride film 106, the silicon
nitride film 103, the silicon oxide film 105, and the silicon nitride film 106 which cover the

membrane region 113 overlap the semiconductor substrate 101. In other words, each
20 edge of the silicon nitride film 103, the silicon oxide film 105, and the silicon nitride film

106 is located on the semiconductor substrate 101. On the other hand, the lower electrode
104 formed of the conductive film in the vibrating film 112 is formed within the membrane

region 113 so as not to overlap the semiconductor substrate 101. In short, the edge of the
lower electrode 104 is located within the membrane region 113. This enables control of

25 the resonance frequency characteristic of the vibrating film 112 by adjusting each thickness
of the silicon nitride film 103, the silicon oxide film 105, and the silicon oxide film 106.

In other words, the capacitance component that varies upon receipt of pressure from

outside in the condenser can be controlled easily, attaining a small-size and highly-sensitive electret condenser.

[0029] A description will be given below to the reason why the silicon nitride film 103 and the silicon nitride film 106 are formed so as to cover the lower electrode 104 and the silicon oxide film 105. When an electret formed of a silicon oxide film comes in contact with a liquid, the charge in the electret is reduced significantly. In the present embodiment, in order to control such reduction in charge of the electret, at least the surfaces (the upper surface, the lower surface, and the side surface) of the silicon oxide film 105 serving as the electret are covered with the silicon nitride film 103 and the silicon nitride film 106. In detail, the silicon nitride film 106 covers completely even the inner wall faces of the leak holes 107 formed in the vibrating film 112 so as not to expose the silicon oxide film (electret) 105 in the leak holes 107. This realizes an electret condenser excellent in moisture resistance and thermal resistance.

[0030] FIG. 5 is a plan view of the silicon nitride film 114 composing the fixed film 110 in the electret condenser of the present embodiment. As described above, the plurality of acoustic holes 111 are formed in the fixed film 110 formed above the semiconductor substrate 101 and the membrane region 113. The acoustic holes 111 are arranged in the membrane region 113 and the surrounding region thereof (part of an external region of the membrane region 113).

[0031] An operation of the electret condenser of the present embodiment will be described below. In the electret condenser of the present embodiment shown in FIG. 3, upon receipt of sound pressure from above through the acoustic holes 111 and the air gap 109, the vibrating film 112 vibrates up and down mechanically in response to the sound pressure. The electret condenser of the present embodiment is a parallel-plate condenser which uses the lower electrode 104 of the vibrating film 112 and the conductive film 118 of the fixed film 110 as electrodes. Accordingly, vibration of the vibrating film 112 changes the distance between the lower electrode 104 and the conductive film 118 to

change the capacitance (C) of the condenser. The charge (Q) capable of being accumulated in the condenser is fixed, and therefore, change in capacitance (C) of the condenser causes the voltage (V) between the lower electrode 104 and the fixed film 110 (the conductive film 118) to change. The reason for this is that the condition given by the following expression (1) must be satisfied physically.

[0032]
$$Q = C \cdot V \quad \dots (1)$$

Further, since the lower electrode 104 is electrically connected to the gate of the FET portion 20 in FIG. 2, change in voltage (V) between the lower electrode 104 and the fixed film 110 (the conductive film 118) changes the gate potential of the FET portion 20. Thus, the gate potential of the FET portion 20 changes in response to the vibration of the vibrating film 112, and the change in gate potential of the FET portion 20 is output to the external output terminal 29 in FIG. 2 as a voltage change.

[0033] Incidentally, large variation in capacitance of a condenser in an air gap formation region of the ECM causes significant influence on the performance of the ECM.

[0034] In contrast, in the present embodiment, respective parts of the fixed film 110 and the vibrating film 112 exposed in the air gap 109 are formed of the insulating films, specifically, the silicon nitride films (the silicon nitride film 114 and the silicon nitride film 106), which have tensile stress. In other words, the silicon nitride films cover the upper surface and the lower side of the silicon oxide film 108 in which the air gap 109 is formed.

This prevents the vibrating film 112 and the fixed film 110 from sticking to each other by surface tension in forming the air gap 109. Accordingly, the thickness of the air gap 109, which determines the capacitance of the condenser in the region where the air gap 109 is to be formed, can be determined according to the film thickness of a thin film (the silicon oxide film 108 in the present embodiment) formed by a semiconductor microfabrication technique or the like, so that the air gap 109 can have a desired thickness. This attains a smaller-size and higher-performance electret condenser with less characteristic variation.

[0035] Hence, according to the present embodiment, a highly-reliable, small-size, and

high-performance microphone can be contemplated. Further, various practical devices equipped with the microphone can be supplied widely to the public.

[0036] It should be noted that the silicon nitride films (the silicon nitride films 106 and 114) are used at the respective parts of the fixed film 110 and the vibrating film 112 exposed in the air gap 109, but any other kind of insulating films may be used only if it has tensile stress.

[0037] Further, in the present embodiment, any of silicon or polysilicon doped with an impurity, gold, refractory metal, aluminum, and aluminum-containing alloy, and the like may be used as a conductive material of the lower electrode 104.

[0038] As well, in the present embodiment, any of silicon or polysilicon doped with an impurity, gold, refractory metal, aluminum, and aluminum-containing alloy, and the like may be used as a material of the conductive film 118 composing the fixed film 110.

[0039] Moreover, in the present embodiment, a substrate made of an insulating material may be used rather than the semiconductor substrate 101.

[0040] In addition, in the present embodiment, the silicon oxide film 108 is used as an insulting film (sacrificial layer) for forming the air gap 109 but the kind of the sacrificial layer is not limited especially. Also, the sacrificial layer may be a lamination layer of a plurality of insulating films made of the same material. This minimizes variation in thickness of the sacrificial layer, in turn, minimizes variation in thickness of the air gap, compared with a case using as the sacrificial layer a single-layer insulating film having the same thickness, with a result of further minimization of characteristic variation of the electret condenser.

Industrial Applicability

[0041] The present invention relates to an electret condenser including a vibrating electrode and a fixed electrode. When applied to an ECM or the like formed using a MEMS technology, the present invention can realize a high-performance and highly-reliable ECM, and therefore, is very useful.